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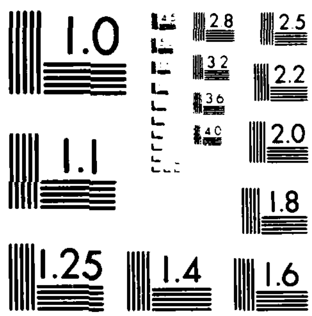

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AFWAL-TR-84-2050

DECISION RECOMMENDATION BOARD (DRB) REPORT - TRANSITION OF SHALE JP-4 TO THE OPERATIONAL VALIDATION PHASE

May 1984

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AERO PROPULSION LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This technical report has been reviewed and is approved for publication.

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The HQ USAF Program Management Directive ~~dated~~ 18 September 1980 for PE71112F established an Air Force commitment to begin the Operational Validation of JP-4 fuel made from shale oil in 1984. The Air Force Logistics Command (AFLC) was designated as the implementing command. The Air Force Systems Command ~~(AFSC)~~ was designated as participating command and given specific responsibilities for providing product quality, performance, system safety and environmental and health assurances prior to the start of any operational validation testing. The Shale JP-4 Decision Recommendation Board (DRB) was established in August 1983 by the Commander, Aeronautical Systems Division, to provide an independent assessment of the acceptability of transitioning shale JP-4 fuel to the Operational Validation Phase. This report addresses the acceptability of transitioning shale JP-4 to Mountain Home AFB, Idaho, and Hill AFB, Utah, the two bases selected by the Air Staff for the Validation Program. Extensive shale JP-4 fuel properties characterization and aircraft system testing have been conducted by AFSC primarily under the Aero Propulsion Laboratory's PE63215F,

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INTRODUCTION:

In August 1983, Lieutenant General Thomas H. McMullen, Commander of Aeronautical Systems Division (ASD), approved the establishment of a Shale JP-4 Decision Recommendation Board (DRB). The DRB was chartered to conduct an independent assessment of the overall acceptability of introducing shale JP-4 at Mountain Home AFB, Idaho and Hill AFB, Utah in 1984 for a two- to four-year Operational Validation Phase by AFLC. F/EF-111A and F-16 aircraft, respectively, are the primary aircraft deployed at these bases. A Working Group comprised of appropriate ASD and other Air Force technical representatives provided direct technical support to the DRB.

This report summarizes the DRB/Working Group's evaluation of the planned introduction of shale JP-4 at Mountain Home and Hill Air Force Bases.

BACKGROUND:

Worldwide petroleum crude resources are gradually deteriorating in quality and diminishing in availability. Additionally, the United States is still strongly dependent upon foreign oil to meet energy demands. Consequently, we are vulnerable to the threat of oil supply disruptions, as experienced in the 1970s, caused by economic and potential international conflicts. Currently, the price of fuels appears to have stabilized although at a much higher level than a few years ago; the long-term projection however is for further cost increases to occur. Fortunately, the US possesses 80% of the known world shale reserves representing 1+ trillion barrels (bbl) of recoverable oil. The western United States Green River area is particularly attractive because of its estimated 600+ billion bbl of reserves in place from shale with an assay exceeding 25 gal/ton. The oil shale in this region is a fine-grained sedimentary rock containing a solid organic material called "kerogen". Kerogen is of high molecular weight and has low solubility in solvents. Recovery requires heating the rock to high temperatures (approximately 1000°F) and collecting the pyrolysis products: shale oil and hydrocarbon gases. Utilizing special processing technologies, shale oil can be converted to excellent specification petroleum products. Shale oil is not competitive with conventional petroleum at today's prices, however it is likely that the current posture will change. In summary, the shale reserves provide an excellent opportunity for the US to become less dependent on foreign petroleum crude providing development activity can be incentivized.

In June 1980, Congress passed the Energy Security Act which provided for the formation of the US Synthetic Fuels Corporation (SFC) and amended the Defense Production Act of 1950 to provide

for synthetic fuels for the Department of Defense (DOD). A subsequent law, P.L. 96-304, appropriated up to $20 billion for financial incentives to foster a national synthetic fuel industry. The initial synthetic fuel project funded under the Energy Security Act was the Union Oil Parachute Creek project in Colorado with an expected shale oil production start date in late 1983 at a rate of 10,000 bbl per day. The Defense Fuel Supply Center (DFSC) contracted with Gary Energy Refining Company, Fruita, Colorado to provide approximately 5000 bbls/day of shale JP-4, using crude from the Parachute Creek project, with initial deliveries to begin in January 1984.

The Air Force immediately accelerated preparations for the eventual operational use of shale derived fuels for turbine engine aircraft. Toward this objective, HQ USAF Program Management Directive L-Y 0106(1) for PE71112F, "Operational Validation of JP-4 Fuel Made From Shale Oil", dated 18 September 1980, officially designated AFLC as he implementing command beginning in 1984. AFSC was designated as participating command and given specific responsibilities for providing product quality, performance, system safety and environmental and health assurances prior to the start of any Operational Validation testing. AFSC research, development, test and evaluation (RDT&E) activities were already well underway under PE 63215F - Aviation Turbine Fuels Technology - which is managed by the Aero Propulsion Laboratory (AFWAL/PO). A special Ad Hoc Committee (which included AFLC representation) had been convened in early 1980 by the ASD Deputy for Engineering (ASD/EN) and AFWAL/PO to establish pertinent RDT&E efforts required for the near-term transition of shale JP-4 and, later, a multisource, broad-property JP-4 fuel product. The near-term program recommended by this committee and endorsed by AFWAL/PO and ASD/EN provided the basic elements for the accelerated 63215F shale JP-4 pre-validation test program. It embodied fuel processing, fuel characterization, component and subsystem testing, system safety engineering analysis and, depending on the availability of test fuel, flight test evaluation. The DRB essentially replaces the earlier Ad Hoc Committee, to provide an independent overall final assessment of the acceptability of transitioning shale JP-4 to the Operational Validation Phase.

The DFSC also initiated procurement of shale JP-4 test fuel to support the AFSC pre-validation test program. After several unexpected delays, a contract was awarded in the Fall of 1982 to Geo-Kinetics and Caribou Four Corners Refinery for production of up to 30,000 bbls of shale JP-4. Because of processing equipment difficulties at the refinery, delivery of fuel did not begin until June 1983. Only a few months remained for completion of testing to meet the original December 1983 transition date for the Operational Validation Program. Barring unexpected difficulties, timely accomplishment of planned testing was still

considered achievable. By April 1983, the Air Force had announced selection of Mountain Home and Hill AFBs for the Operational Validation Phase. These selections were primarily driven by geographical logistics and daily fuel demand versus availability considerations.

Because of the delay in the availability of test fuel and with the selection of Mountain Home and Hill AFBs, the AFWAL/PO pre-validation test program was able to focus on critical components associated with the F/EF-111A and F-16 aircraft, respectively, which are principally deployed at these bases. As efforts progressed, testing delays were also experienced and some additional unplanned tests had to be undertaken. Union Oil Company also encountered problems in bringing their Parachute Creek shale oil recovery operation on stream. As a result, the Air Force officially delayed the planned start of the validation program to some time in the Fall 1984 for Mountain Home and the Winter 1984 for Hill AFB.

DRB/Working Group Charter and Membership

The Charter for the Shale JP-4 Decision Recommendation Board (DRB) specified that the Board, supported by a technical Working Group, shall conduct an independent assessment of the results of the shale JP-4 test and evaluation program in order to establish a recommended ASD position concerning the introduction of this fuel at Hill and Mountain Home AFBs in early 1984 by AFLC for the Operational Validation Phase. Colonel James Freytag, Commander, Air Force Wright Aeronautical Laboratories (AFWAL), was designated DRB Chairman with initial Board representation to be provided by other ASD organizations including the Deputies for Engineering (EN), F-16 (YP), Propulsion (YZ), and Tactical Systems (TA), and the Aero Propulsion Laboratory (PO) and Materials Laboratory (ML), and appropriate representation from AFLC, Arnold Engineering Development Center (AEDC), the Aerospace Medical Research Laboratory (AFAMRL) and Tactical Air Command. Actual DRB membership is indicated in Appendix 1. The Working Group was also comprised of appropriate ASD and other Air Force technical representatives; specific representation is shown in Appendix 2. The Working Group was structured into a Fuel Properties/Quality Assurance Subgroup and an Aircraft Assessment Subgroup for the conduct of its assessment.

The Operational Validation Program Management Directive (PE71112), dated 18 September 1980, assigned several tasks to AFSC which are "essential" to any "go-ahead" decision. These include:

1. Accomplishment of minimum critical component engine and flight tests to assure the safe use of shale JP-4 in operational aircraft.

2. Definition of special shale JP-4 technical requirements for use in procurement of MIL-T-5624.

3. Accomplishment of toxicology study.

4. Accomplishment of a system safety analysis on each type of aircraft programmed to use shale JP-4 exclusively with emphasis on engine and engine accessory compatibility.

5. Measurement of emissions for engines to support the environmental assessment.

6. Establishment of a quality assurance program to assure that shale JP-4 meets the requirements of MIL-T-5624 (specification for conventional JP-4).

These tasks were largely being pursued by AFWAL/PO under PE 63215F, Aviation Turbine Fuel Technology Program, with significant participation by AFAMRL and other ASD organizations, particularly ASD/EN, YP, YZ, and AFWAL/ML.

DISCUSSION:

Shale JP-4 versus Conventional JP-4

Conventional JP-4 dates back to 1951 and is basically a wide-cut mixture of heavy naphtha and kerosene with an average boiling range from 61°C to 239°C and possesses a maximum freeze point of -58°C and a Reid vapor pressure of 2 to 3 psi at 38°C. Related to the volatility is an expected flash point of approximately -29°C. While there have been refinements to the fuel specification (MIL-T-5624) to keep pace with engine developments, JP-4 has basically maintained the critical properties first specified to insure availability and to fulfill operational performance requirements. Various additives are used to control corrosion, lubricity, stability, fuel system icing, bacterial growth, etc.

Shale oil syncrude is a premium feedstock. Consequently, with proper refining and inclusion of appropriate additives, it should inherently enable the production of fuel in conformance with the same basic JP-4 fuel specification. Selected property tolerance limits or additive concentration modifications may be necessary to, at a minimum, preserve overall operational acceptability to that commonly expected with conventional JP-4. One of the major objectives of the AFSC RDT&E efforts was to identify any significant differences and establish appropriate revised tolerance limits or additive requirements to assure an acceptable fuel product for use in the Operational Validation Program. Achievement of the latter has entailed only minor modifications to the conventional JP-4 specification. These

changes are: (1) antioxidant additive at maximum concentration - this will assure excellent fuel storage stability; (2) corrosion inhibitor/lubricity additive to be included at the maximum allowable concentration level - this will eliminate the poor lubricity properties associated with highly hydrotreated fuels made from syncrudes; (3) a 20 ppm limit on nitrogen content to assure storage and thermal stabilities and minimize oxides of nitrogen exhaust emissions; and (4) establishment of a minimum aromatic concentration level of 6.5 volume % and Current specification permits a minimum of 0 volume %. However, conventional JP-4 typically contains about 10 volume %. Aromatics cause elastomer swell which is beneficial in reducing fuel leakage in aircraft systems. Shale syncrude products without special processing would normally contain very low aromatics. The 6.5 volume % specification minimum limit for shale JP-4 will assure aircraft fuel system acceptability from fuel system leakage standpoint.

The DRB's following assessment pertains to a shale JP-4 fuel meeting the standard conventional JP-4 specification requirements with the aforementioned modifications incorporated.

Assessment of Shale JP-4 versus Conventional JP-4

The DRB has thoroughly analyzed all aspects of the shale JP-4 pre-validation test activities in order to establish its acceptability from performance, system safety and occupational health and environmental impact viewpoints. This assessment focused largely on the comparative physical and chemical properties of shale derived versus petroleum derived JP-4 fuels as well as their respective performance compatibility with aircraft systems. The DRB placed major emphasis on the F/EF-111A and F-16 aircraft in view of their primary involvement in the planned Operational Validation Phase. As would be expected, the AFSC RDT&E pre-operational validation investigative efforts were designed in many instances to provide direct comparative data between the two differently derived JP-4 fuels. In some areas such as TF30 and F100 engine Accelerated Mission Tests (AMT) existing baseline conventional JP-4 data were utilized for the evaluation.

The DRB assessment of shale JP-4 versus conventional JP-4 in the various pertinent areas is as follows:

- Materials Compatibility

Various fuel system materials, including seals and sealants, structural adhesives, tank coatings, bladder materials, fire suppressant foams, wire insulations and self-sealing hoses, were subjected to accelerated agings in both conventional and shale oil JP-4 fuels by the AFWAL/ML. The results of these tests

showed that there is no significant difference in the compatibility of either shale oil JP-4 or conventional JP-4 for most materials. One sample of shale JP-4, which was later found to be contaminated with a non-approved additive, resulted in Buna N deterioration. Results of accelerated aging tests with Buna N in three additional shale JP-4 samples showed no significant difference when compared with JP-4. Properties measured included % volume change, tensile strength and % elongation of the various materials after six months' storage at 140°F.

- Toxicity/Environmental Impact

A preliminary assessment of the environmental and health factors of shale JP-4 has been completed by the AFAMRL. Based on the similar chemical and physical properties of shale JP-4 versus conventional JP-4, there are no changes in fuel jettisoning, combustion emissions, evaporative emissions, environmental fate, photochemistry, industrial hygiene, toxicity, and engine emissions. Recently, a 90-day continuous inhalation study was completed on shale JP-4 with mice and rats with preliminary results comparable to those on conventional JP-4. Post exposure animal observations and pathology are continuing. Additional industrial hygiene and toxicity studies will be performed by the AFAMRL when samples of the shale JP-4 for the Operational Validation Program are available.

- Aircraft Performance/System Safety

1. F/EF-111A Aircraft: The only high use aircraft at Mt. Home AFB are the F/EF-111A. The AFWAL/PO shale JP-4 pre-test verification program for these aircraft included accelerated mission testing of the TF30 engine, flight tests of an F-111, hanger low temperature aircraft soaks and engine starts at Eglin AFB, and a preliminary hazard analysis.

Testing of the TF30 engine using shale JP-4 was conducted in the sea level engine test stand at the Aero Propulsion Laboratory. The engine completed the equivalent of 973 flight hours (the testing was terminated short of the planned 1000 equivalent hours due to the shortage of fuel for this and other testing). The engine was torn down and inspected at Tinker AFB, Oklahoma by OC-ALC and other Air Force and contractor personnel.

Twenty-six and one-half hours (16 sorties) of general performance type flight testing were completed on an F-111D with TF30-P9 engines. Normal flight test missions with in-flight relight attempts were flown. No adjustments to the engine or airframe systems were made.

The Eglin hanger testing included aircraft cold soaks and engine starts which were performed down to -50°F using cartridges and bleed air as an energy source.

A preliminary hazard analysis of the F-111 aircraft was conducted with emphasis on the potential hazards that might occur due to possible variations in fuel characteristics. Systems sensitive to variations in fuel quality were analyzed including the fuel quantity measurement equipment, fuel storage and transfer equipment and the propulsion system. Specific issues addressed were fuel lubricity, combustion liner cooling, coking/thermal stability, and system redundancy.

A review of all available information and inspection of the TF30 engine following the accelerated mission testing showed no fuel related effects and no abnormal equipment deterioration or performance variations were observed. The preliminary hazard analysis indicated that any increased risk in safety of flight of the F/EF-111A aircraft would be insignificant.

II. F-16 Aircraft: The 388th TFW and 419th TFW (AFRES) are equipped with the F-16 aircraft making it the primary high use aircraft at Hill AFB. For this reason, the predominance of effort relating to the assessment of the compatibility of shale derived JP-4 with the flight operations at Hill AFB focused on the F-16 system.

- F100 Engine Test

A long-term sea level test program was conducted at Pratt & Whitney, West Palm Beach, Florida on the F100-PW-200 engine, which powers the F-16 aircraft, to assess its performance and durability when using the shale JP-4. The engine was subjected to 1810 Total Accumulative Cycles (TAC) which simulate 1000 equivalent flight hours or approximately 54 months of actual service. The main fuel pump had to be replaced at 977 TAC cycles when engine starting difficulties were encountered. Inspection revealed excessive vane stage rotor shaft end wear and fixed sideplate distress. The test was completed with no evidence of further pump problems. The post-test analytical condition inspection was conducted on the engine at SA-ALC by Air Force, prime contractor, and vendor representatives. Compared to previous Pacer Century engine analytical condition inspections using conventional JP-4, the hot gas flowpath was found to be in above average condition. However, worn components were again found in the main fuel pump. None of these components were the same as those worn in the first pump. Excessive wear in the slots of the high rotor speed sensor feedback gimbal was reported

as was scoring of the piston in the pressurizing and dump valve. Analyses of test fuel revealed that the lubricity was marginal due to loss during handling of the additive used to provide the required lubricity.

- F100 Main Fuel Pump Tests

In order to resolve these problems, supplementary shale JP-4/F100 main fuel pump endurance tests were conducted on three sets of hardware. Each set consisted of a main fuel pump, a speed sensor, and a pressurizing and dump valve. Two sets were run at Pratt & Whitney for a total of 660 hours, of which 440 hours were run using shale derived JP-4 and 220 hours were run using conventional JP-4. The third set was run at Chandler Evans, the pump manufacturer, for 682.5 hours using shale derived JP-4. The lubricity of the fuel was carefully controlled to the level that will be used in the operational phase of the program. No fuel related effects were found.

While this endurance test was being conducted, the respective manufacturers of the four items that showed wear during the F100 AMT completed a detailed inspection. Their conclusions were that: (a) the pump wear could have been either fuel or hardware related; (b) the speed sensor wear was probably due to the absence of the specified hard coating on the gimbal, and (c) the scoring of the piston in the pressurizing and dump valve was not abnormal.

- F-16 Flight Test:

An evaluation of JP-4 in the F-16 equipped with the F100-PW-200 engine was conducted by the Air Force Flight Test Center. The purpose of this test was to determine any differences in aircraft operability when using shale fuel versus that for conventional JP-4. Flight Manual engine operating procedures and limitations were observed throughout the test which consisted of eight flights. Engine stability, airstart capability and engine operability were examined with the Unified Fuel Control as well as with the Backup Control. In addition, ground tests were performed to determine fuel leak susceptibility. Both qualitative and quantitative results of these tests indicated no difference in aircraft operation when using shale JP-4. Existing Flight Manual engine operating procedures and limitations are appropriate for the fuel.

- Preliminary System Safety Analysis:

General Dynamics, Fort Worth Division has completed a preliminary system safety analysis of the short-term

effects of shale oil derived JP-4 fuel in the F-16 system. The analysis focused on fuel system, propulsion and fire and explosion hazards using worst case conditions where specific test data was not available. General Dynamics indicates that "the results of the study do not indicate any significant problems with the use of shale oil derived JP-4." General Dynamics is continuing testing for the Air Force which relate to the long-term safety associated with F-16 component durability and material compatibility. The results of these tests will be available in January 1985. In view of General Dynamics' favorable assessment of short-term safety effects as well as the overall "positive" results associated with all other aspects of the Air Force's shale JP-4 RDT&E efforts, go-ahead approval with the planned implementation of shale JP-4 at Hill AFB for the Winter 1984 is considered appropriate. Any "negative" long-term effects which are subsequently identified by General Dynamics should be assessed by ASD/YP and SA-ALC/MM and SF to determine impact on Operational Validation Program monitoring/assessment procedures in order to assure preservation of an acceptable safety-of-flight posture.

A review of all available information indicates that with proper control of the fuel properties no fuel related effects should be encountered during use of shale derived JP-4 in F-16 operational aircraft.

III. Auxiliary Power Equipment:

The GTCP 85-180 power turbine combustor was tested as representative of the types of combustion systems used in AF ground power unit turbines. The GTCP 85-180 is currently in the M32A/60A ground cart used to start the F/FB-111 aircraft. The testing was accomplished by the manufacturer using shale JP-4 and included a combustion rig and a fuel atomizer bench assessment. The combustion rig was operated at standard, hot, and cold day conditions and at sea level and altitude.

The shale JP-4 showed an improvement in ignition capability at all test conditions but generally shale derived fuel test results were comparable to conventional derived fuel performance.

The performance of the F-16 aircraft jet fuel starter (T-62T-40-8) was also evaluated using shale JP-4. Testing was in accordance with the initial fuel-related qualification requirements for the F-16 starting system and included motoring runs, repeated starts at both rapid cycling rates and at five-minute shutdown intervals, and starts at altitude. Tests were first performed using shale JP-4 in a production turbine. Subsequently, the identical tests were rerun on the same turbine

using conventional based fuel. The engine was calibrated before and after each series of tests as a check on possible engine deterioration. To ensure a comparison between the test results, a new turbine wheel and other selected hot-end components were used for each fuel. There was no significant difference in performance of the engine when run on the two fuels. Detailed dimensional measurements of the fuel pump showed no measurable degradation in pump performance. Combustor liner temperatures showed the use of shale JP-4 fuel will not adversely affect the engine life.

In view of the above, no difference in performance is anticipated for the auxiliary power equipment at Hill and Mountain Home AFBs when operated on shale JP-4.

IV. <u>Transient Aircraft</u>:

Transient aircraft refueled at Hill and Mountain Home AFBs also will receive shale JP-4. The fuel system design practices for these commercial and visiting military aircraft are similar to the practices used for the aircraft and equipment assessed in the AFWAL/PO program. This, combined with the relatively short-term operation on shale fuel, mitigates any concern for their safety of flight. However, it is likely that some Army helicopters could experience more than a random use of shale fuel. The Army conducted a 150-hour shale fuel test on each of three helicopter engines of the type expected to receive the fuel at these bases. No problems occurred during the testing. In view of this information, the DRB considers the use of shale fuel in transient aircraft to be low risk.

- <u>Quality Assurance, Handling and Storage</u>

Fuel quality control procedures at the Gary Refinery storage facilities at Salt Lake City and storage facilities at Mountain Home and Hill AFBs have been reviewed. In general, these procedures follow standard Air Force practice to assure high quality fuel meeting specification requirements is delivered to the aircraft. Added emphasis is being placed on monitoring fuel lubricity which warrants special controls as a result of the lessons learned during the shale RDT&E Phase. Ball-on-Cylinder test apparatus has been furnished to Mountain Home and Hill AFB to facilitate on-site monitoring of fuel lubricity of the fuel in storage tanks and in refueler fill stands to ensure that fuels have adequate fuel lubricity properties. In view of the emphasis in the latter area as well as the other special fuel properties monitoring activities that will be pursued during the Operational Validation Phase, overall quality assurance is considered to be superior to that for conventional JP-4.

- Fuel Effects Monitoring Plan

The fuel effects monitoring plan includes quarterly analyses of all Work Unit Codes (WUC) for the operational validation aircraft engines (WUC 23xxx) and fuel systems (WUC 46xxx) using the Maintenance Data Collection System (D056). A two-year historical data base will be assembled for systems at Mountain Home and Hill AFBs, and control groups will be established at other bases where similar systems use conventional JP-4. The analyses will compare maintenance data for operational validation aircraft against the historical and control group data. These analyses will identify increased or decreased maintenance requirements by monitoring twenty-one malfunction codes related to the following categories: wear, corrosion, leaks, coking, overheating, or starting problems. Additionally, the first three F100 engine main fuel pumps to reach 400 hours of operation on shale JP-4 will receive tear down inspection. Tear Down Reports (TDRs) will also be accomplished on failed F-111 and F-16 system components considered sensitive to fuel properties. Analytical Condition Inspections (ACI)s will be performed on two high use TF30 and two F100 engines following 18 months use of shale JP-4.

CONCLUSIONS:

Adequate pre-validation testing of shale JP-4 has been conducted under PE63215F - Aviation Turbine Fuel Technology to fulfill AFSC tasking assignments under PE71112F - Operational Validation of JP-4 Fuel Made from Shale Oil. As a result of a thorough review and analysis of pertinent RDT&E activities, the DRB concludes that:

I. Shale JP-4 represents a high quality fuel product which meets all the requirements of the current MIL-T-5624L specification for conventional JP-4 fuel. Minor modifications to MIL-T-5624L for acquisition of shale JP-4 fuel for the Operational Validation Program will provide further guarantee of product quality in the field. These modifications include: a 20 ppm limit for nitrogen content; establishment of a minimum aromatics concentration level of 6.5 volume %; and a requirement for incorporation of antioxidant and corrosion inhibitor (lubricity) additives at specification's current maximum allowable concentration levels.

II. Shale JP-4 conforming to the modified MIL-T-5624L specification exhibited materials compatibility performance comparable to the conventional JP-4 fuel. Materials encompassed all types currently utilized with conventional JP-4 fuel in aircraft, fuel storage and ground support equipment.

III. Based on the similar chemical and physical properties of shale JP-4 versus conventional JP-4 there are no changes in

fuel jettisoning, combustion emissions, evaporative emissions, environmental fate, photochemistry, industrial hygiene and toxicity. With respect to an environmental impact analysis, in accordance with AFR 19-2, the SA-ALC was given a "categorical exclusion" in 1981 for the Operational Validation Program. Shale JP-4 toxicological and environmental assessments will continue through the Operational Validation Phase.

IV. Aircraft component and limited flight test evaluations indicate overall acceptable performance with shale JP-4 fuel. Testing included accelerated mission tests on TF30 and F100 engines, supplementary F100 main fuel pump tests, and flight assessments on an F-16 and F-111D aircraft. The detailed inspection of the F100 AMT main fuel pump and the supplementary main fuel pump tests have satisfactorily alleviated any serious concern with fuel related pump effects. The Board is of the opinion that the AMT pump effects, if fuel related, was most likely attributable to corrosion inhibitor (lubricity) additive deficiency in the shale JP-4 test fuel. Modification to MIL-T-5624L for shale JP-4 procurement will require maximum allowable corrosion inhibitor concentration. The latter, in conjunction with the special fuel lubricity monitoring procedures which will be implemented at the test bases, should provide more than adequate safety-of-flight assurance.

V. No safety-of-flight changes with the use of shale JP-4 have been identified. F/EF-111A and F-16 aircraft will be operating exclusively on shale JP-4 at Mountain Home AFB and Hill AFB, respectively. Preliminary hazard analyses, conducted by SM-ALC/MM for the F/EF-111A and by General Dynamics in support of ASD/YP for the F-16 aircraft, indicated anticipated operational risks should be comparable in all respects to conventional JP-4. These analyses utilized RDT&E results relating to fuel-wetted components, fuel system and engine performance, materials compatibility and fire safety considerations.

VI. Use of shale JP-4 for both commercial and military transient aircraft approved for conventional JP-4 at Mountain Home and Hill AFBs is considered acceptable from both performance and safety-of-flight viewpoints. This position is supported by the favorable F/EF-111A and F-16 aircraft systems RDT&E results; satisfactory completion of 150-hour shale fuel tests by the Army on several helicopter engines; the fact that shale JP-4 will conform fully with the conventional JP-4 MIL-T-5624L specification requirements; and only short-term, limited shale JP-4 utilization is involved (albeit no long-term degradation effects are expected, even with exclusive use of the fuel).

RECOMMENDATION:

In view of the overall favorable results of shale JP-4 prevalidation testing, the DRB strongly endorses an affirmative position by ASD to HQ AFSC concerning issuance of an official "go-ahead" approval for the transition of shale JP-4 to the Operational Validation Phase. This approval should be contingent on the acquisition of shale JP-4 for Mountain Home and Hill AFBs in conformance with the modified MIL-T-5624L specification.

APPENDIX 1

SHALE JP-4 DECISION RECOMMENDATION BOARD (DRB)

- <u>ORIGIN</u>:
  - Established in August 1983 by ASD/CC.
  - Supersedes previous Ad Hoc Committee
- <u>CHARTER</u>:
  - Conduct independent, comprehensive assessment of the overall acceptability of transitioning shale JP-4 to the Operational Validation Phase.
- <u>DRB MEMBERS</u>:

AFWAL/CC	Col J. Freytag (Chairman)	ASD/YPEF	Mr R. Grimm
AFWAL/PO	Col J. Johnson	ASD/YZA	Dr D. McErlean
SA-ALC/SF	Col S. Richardson	AFAMRL/TH	Col M. MacNaughton
SM-ALC/MM	Col J. Serur	AEDC/Sverdrup	Mr R.E. Smith, Jr.
ASD/ENF	Mr E. Abell	ASD/TACSO-A	MSgt K. Murphy
ASD/TAE	Lt Col J. Holler	AFOTEC (Advisory)	Maj R. Hartman
OO-ALC/MMARA	Mr D. Horne		
HQ USAF/LEYSF	Col G. Custer		
AFWAL/MLS	W. Johnson		

APPENDIX 2

SHALE JP-4 WORKING GROUP

CO-CHAIRMEN: Mr B. Botteri AFWAL/POS
Mr R. Ivan ASD/ENFP

SUBGROUP I
FUEL PROPERTIES/QUALITY ASSURANCE

LEADER: A. Churchill	AFWAL/POSF
W. Berner	ASD/TAES
C. Delaney	AFWAL/POSF
Maj L. Dipoma	SA-ALC/SFTH
P. House	AFWAL/MLSE
H. Lander	AFWAL/POSF
Maj J. Martone	AFAMRL/TH
P. Tydings	AFWAL/MLSE

SUBGROUP II
AIRCRAFT ASSESSMENT (F-16, F-111, OTHER)

LEADER: C. Bleidorn	ASD/ENFPJ
C. Bentz	AFWAL/POTC
N. Bertram	ASD/ENFEF
R. Bradley	AFWAL/POSF
A. Burwell	AEDC/DOPT
P. Colegrove	AFWAL/POOS
J. Crouch	ASD/YZEF
M. Fellows	ASD/ENFTA
G. Kline	ASD/YPEF
M. Lustig	ASD/SES
MSgt K. Murphy	ASD/TACSO-A
W. Rudhman	ASD/YZEF
R. McGregor	SM-ALC/MMKRD
Lt J. Vance	AFWAL/POTX
R. Wulf	ASD/TAEF

GLOSSARY OF TERMS

I. Air Force Logistics Command (AFLC)

OC-ALC	Oklahoma City Air Logistics Center Tinker AFB, Oklahoma
OO-ALC	Ogden Air Logistics Center Hill AFB, Utah
OO-ALC/MMARA	Aircraft Systems/Engineering Reliability
SA-ALC	San Antonio Air Logistics Center Kelly AFB, Texas
SA-ALC/SF	Energy Management Directorate
SA-ALC/SFTH	Technical Assistance Team
SM-ALC	Sacramento Air Logistics Center McClellan AFB, California
SM-ALC/MM	Material Management Directorate
SM-ALC/MMKRD	F-111 Systems Engineering

II. Air Force Systems Command (AFSC)

AEDC	Arnold Engineering Development Center Arnold AFS, Tennessee
AEDC/DOPT	Engine Test and Evaluation Division
AFAMRL	Air Force Aerospace Medical Research Laboratory Wright-Patterson AFB, Ohio
AFAMRL/TH	Toxic Hazards Division
AFAMRL/THT	Toxicology Branch
ASD	Aeronautical Systems Division Wright-Patterson AFB, Ohio
ASD/CC	Commander, Aeronautical Systems Division
ASD/ENF	Deputy for Engineering/Directorate of Flight Systems Engineering
ASD/ENFEF	Flight Equipment Division, Fuels and Hazards Branch
ASD/ENFP	Propulsion Division

ASD/ENFPJ	Installation Branch
ASD/ENFTA	Flight Technology Division, Aeronautics and Performance Branch
ASD/SES	System Safety Office
TACSO-A	(Tenant Organization) Tactical and Command Systems Office
ASD/TAE	Deputy for Tactical Systems/ Directorate of Engineering
ASD/TAEF	Flight Systems Division
ASD/TAES	Analysis and Support Division
ASD/YPE	Deputy for F-16, Directorate of Engineering
ASD/YPEF	Flight Systems Division
ASD/YZA	Deputy for Propulsion, Airlift and Trainer Engines Office
ASD/YZEF	Deputy for Propulsion, Directorate of Engineering, Tactical Engines Division
ASD/YZFS	Deputy for Propulsion, Tactical Engines Program Office, Special Projects Division
AFWAL	Air Force Wright Aeronautical Laboratories
AFWAL/CC	Commander
AFWAL/MLS	Materials Laboratory, Systems Support Division
AFWAL/MLSE	Materials Engineering Branch
AFWAL/PO	Director, Aero Propulsion Laboratory
AFWAL/POOS	Aerospace Power Division, Power Systems Branch
AFWAL/POS	Fuels and Lubrication Division
AFWAL/POSF	Fuels Branch
AFWAL/POTX	Turbine Engine Division, Technology Branch

III. OTHER

DFSC	Defense Fuel Supply Center Alexandria, Virginia
AFOTEC	Air Force Operational Test and Evaluation Center Kirtland AFB, New Mexico
ASTM	American Society for Testing and Materials
Crude Petroleum	A naturally occurring mixture, consisting predominantly of hydrocarbons and/or sulfur, nitrogen, and/or oxygen derivatives of

hydrocarbons, which is removed from the earth in liquid state or is capable of being so removed. Crude petroleum is commonly accompanied by varying quantities of extraneous substances such as water, inorganic matter, and gas.

Environmental Fate — Pertains to the transport, alteration, persistence and/or destruction of a fuel or compound following its release into the surrounding air, water and soil, as well as its potential effects on living organisms during each step.

Heavy Crude Oil — Crude oil containing a weighted average gravity of 20.0 degrees API or less corrected to 60°F.

Oil Shale — A range of sedimentary shales containing organic matter (kerogen) that can be converted into crude shale oil, gas, and carbonaceous residue by destructive distillation.

Reid Vapor Pressure — The measure of pressure exerted on the interior of a specified container (Reid vapor pressure apparatus), under a specified test condition of 100°F.

Shale Oil — A liquid similar to conventional crude oil that is obtained by processing organic mineral (kerogen) in oil shale, a sedimentary-type rock.

Sour Crude Oil — A crude that contains sulfur in amounts greater than 0.5 to 1.0 weight percent or that contains 0.05 cubic feet or more of hydrogen sulfide (H_2S) per 100 gallons.

Sweet Crude Oil — A crude that does not contain hydrogen sulfide and has below 0.5 weight percent sulfur content with only a minor portion of the sulfur content being present as mercaptan compounds.

Syncrude	The liquid hydrocarbons produced from organic deposits, such as oil shale, tar sands, and coal which have been subjected to refinery pre-processing to remove undesirable metals, minerals, etc.
Tar Sands	Consolidated or unconsolidated rocks with interstices containing bitumen that ranges from very viscous to solid. In a natural state, tar sands cannot be recovered through primary methods of petroleum production.

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